Space Weather Technical Forecast

Issued on Saturday, 10 February 2024 at 13:40 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Current S2 conditions likely declining. Further R1-R2 Radio Blackouts Likely. Chance of G1/G2 conditions day 3 (12 Feb).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity recorded at GOES16 has been High over the past 24 hours, with one major X-class flare observed, this seeing a peak recorded magnitude of X3.3 at 09/1314UTC, and most likely associated with Ex-AR3575 which now lies over the southwestern limb. Three M-class flares were also observed.

There are currently nine regions on the visible disc, three of which are unnumbered. AR3576 remains the dominant spot in terms of complexity and size. There continues to be slight development in the collections of spots on its leading northern edge, there are also at least three delta regions evident in the intermediate region. Magnetic looping suggests a lack of tight and complex fields though, likely the reason for the lack of large flares from this region. All other spots are relatively simple and unremarkable. Two new regions have appeared on the disk, a simple Hsx region which has rotated around the limb and a small Cro in the northeast.

Two potentially Earth-directed CMEs were observed. One shock from the X-class flare and a CME from near south-centre disk associated with a potential filament disturbance and long period high-level C-class flare around 0700 on 10 Feb. Analysis of this eruption is still taking place.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by ACE and DSCOVR at L1, were indicative of a weak CME arrival around 09/2140 UTC. Slightly Elevated winds speeds fell to background before becoming slightly elevated once again around 09/2140UTC. This likely the glancing arrival of the 06 Feb CME, resulting in winds increasing to around 490km/s, before subsequently declining to around 380km/s by the end of the period. This general evolution applied to most solar wind characteristics, with density generally average, peaking around 10ppcc just before CME arrival. The IMF generally weak below 6nT but briefly peaking into moderate levels with the CME arrival. The north-south component varying weakly between -4 and +7nT, and largely positive following CME arrival. The mainly positive phi angle (away from the Sun) changed to increasingly negative later in the period. Geomagnetic activity generally Quiet, but with Unsettled condition (Kp3) recorded following the CME arrival.

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux rose steadily following the X3.3 flare, rising above S1 levels (10pfu) from 09/1549UTC and S2 levels (100pfu) from 09/1815UTC, where despite some slight fluctuations it remains.

GOES16 high energy (greater than 2MeV) electron flux remained at Normal Background levels. The associated 24-hour fluence was well below the Active (1e8 integrated pfu) threshold and has had a flat trend, with a 10/0001UTC fluence value of 1.62e6 pfu observed.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate X-ray flare activity likely, and a slight chance of further X-class activity, with AR3576 providing the vast majority of the risk as Ex-AR3575 continues to rotate further

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onto the far side of the disk.

Solar Wind / Geomagnetic Activity: There are up to 3 CMEs which currently feature in the forecast, all perhaps enhancing the solar wind environment on day 2 (12 Feb). The first is a CME from 08 Feb arriving around 12/1200UTC. The second is associated with the potential shock effects from the large CME associated with the X3.3 event, perhaps with shock effects anytime between 11/0900-12/2359 UTC. Finally there was an eruption near south-centre disk on 10 Feb, with possible arrival any time from early on day 3 (12 Feb). Confidence is low for each CME influence at this point in time. No coronal hole fast wind enhancements are expected.

Quiet to Unsettled conditions are expected to start. The shock from the X3.3 flare brings a slight chance of G1 conditions on day 2 (11 Feb), with this becoming a chance of G1/G2 on day 3 (12 Feb) and an outside chance of a G3 should all three possible CMEs arrive in quick succession. Lingering CME effects are possible by day 4 (13 Feb), though overall geomagnetic activity should fall back to Quiet to Unsettled with a chance of Active.

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux is currently at S2 levels following the X3.3 flare on 09 Feb. The high energy proton flux should begin to subside through the period, though likely remaining above S1 and perhaps S2 through day 1 (10 Feb), with a gradual fall to below S1 levels possibly by day 3 (12 Feb).

High energy electron flux (greater than 2MeV) is expected to continue at current Normal Background levels, with the associated 24-hour electron fluence remaining well below the Active threshold.

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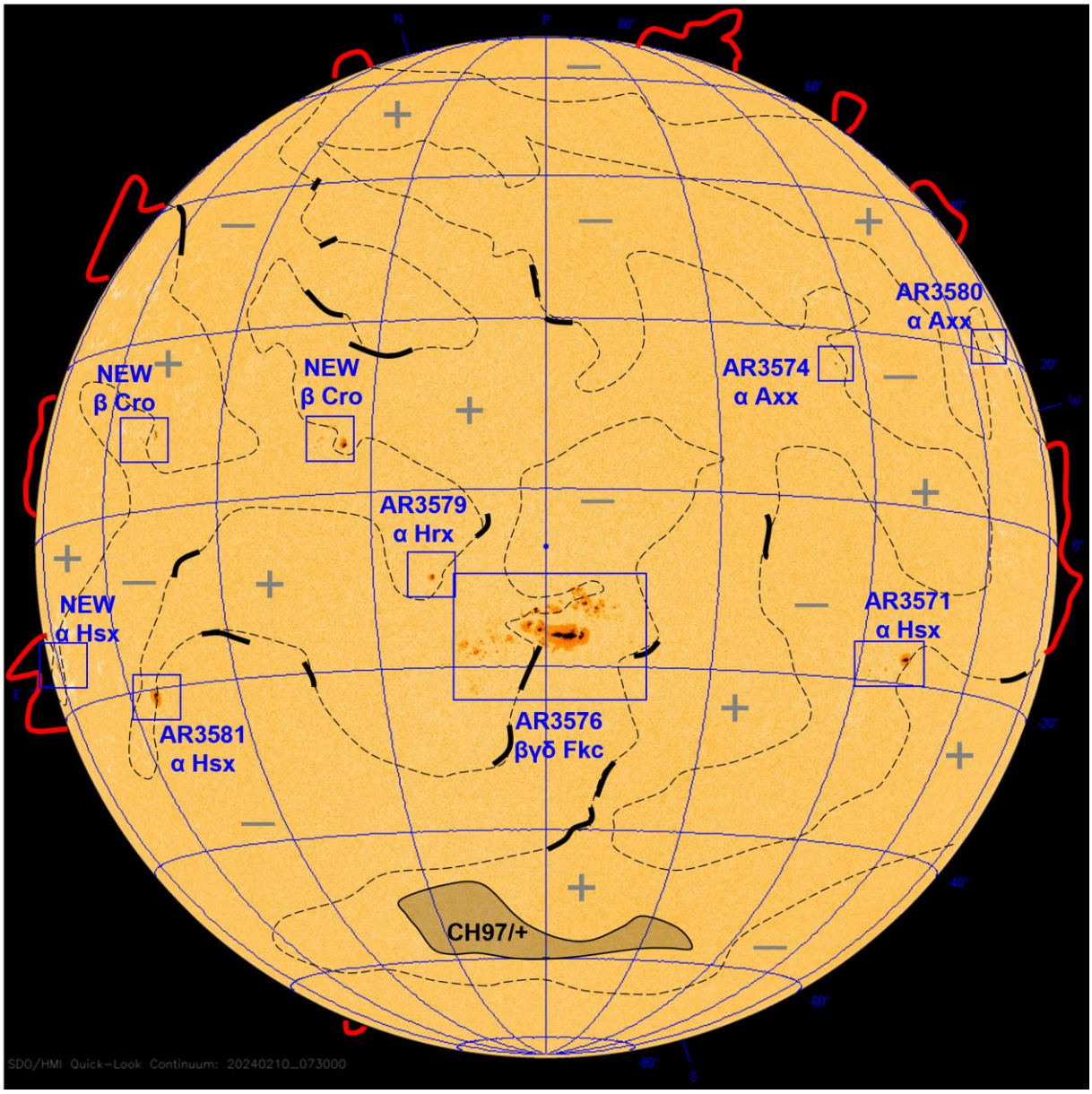
Figure 1. Solar Analysis Valid 10/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are up to 3 CMEs which currently feature in the forecast, all perhaps enhancing the solar wind environment on day 2 (12 Feb). The first is a CME associated with the 08/2030 UTC south-centre filament eruption. This is modelled as crossing 1AU, mainly behind and below the Sun-Earth line around 12/1200UTC. The second is associated with the potential shock effects from the large CME associated with the X3.3 event. Despite the position of this event around the southwest limb, given the size of the eruption and position of the parker spiral some shock enhancement may be possible anytime between 11/0900-12/2359 UTC. Finally there was an eruption near south-centre disk associated with a potnetial filament disturbance and long period high-level C-class flare around 0700 on 10 Feb. Analysis of this eruption is still taking place, though current calculations indicate a possible arrival any time from early on day 3 (12 Feb). Confidence is low for each CME influence at this point in time.

No coronal hole fast wind enhancements are expected within the forecast period, therefore the background solar winds should remain similar with a chance of rising to slightly elevated at times.

Quiet to Unsettled conditions are expected to start the four-day period. The shock from the X3.3 flare brings a slight chance of G1 conditions on day 2 (11 Feb), with this becoming a chance of G1/G2 on day 3 (12 Feb) and an outside chance of a G3 should all three possible CMEs arrive in quick succession. Lingering CME effects are possible by day 4 (13 Feb), though overall geomagnetic activity should fall back to Quiet to Unsettled.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	10	40	10
Strong	G3	No	1	1	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
08/2030	Partial	Filament Eruption	S centre	641 km/s	12/1200UTC	Glancing Blow
09/1507	Partial	X3.3	Around W Limb	2222 km/s	11/0900-12/2359	Shock
10/1058	Partial	Filament disturbance	S Centre	930 km/s	12/0500	Awaiting ENLIL

Figure 2: MOSWOC ENLIL

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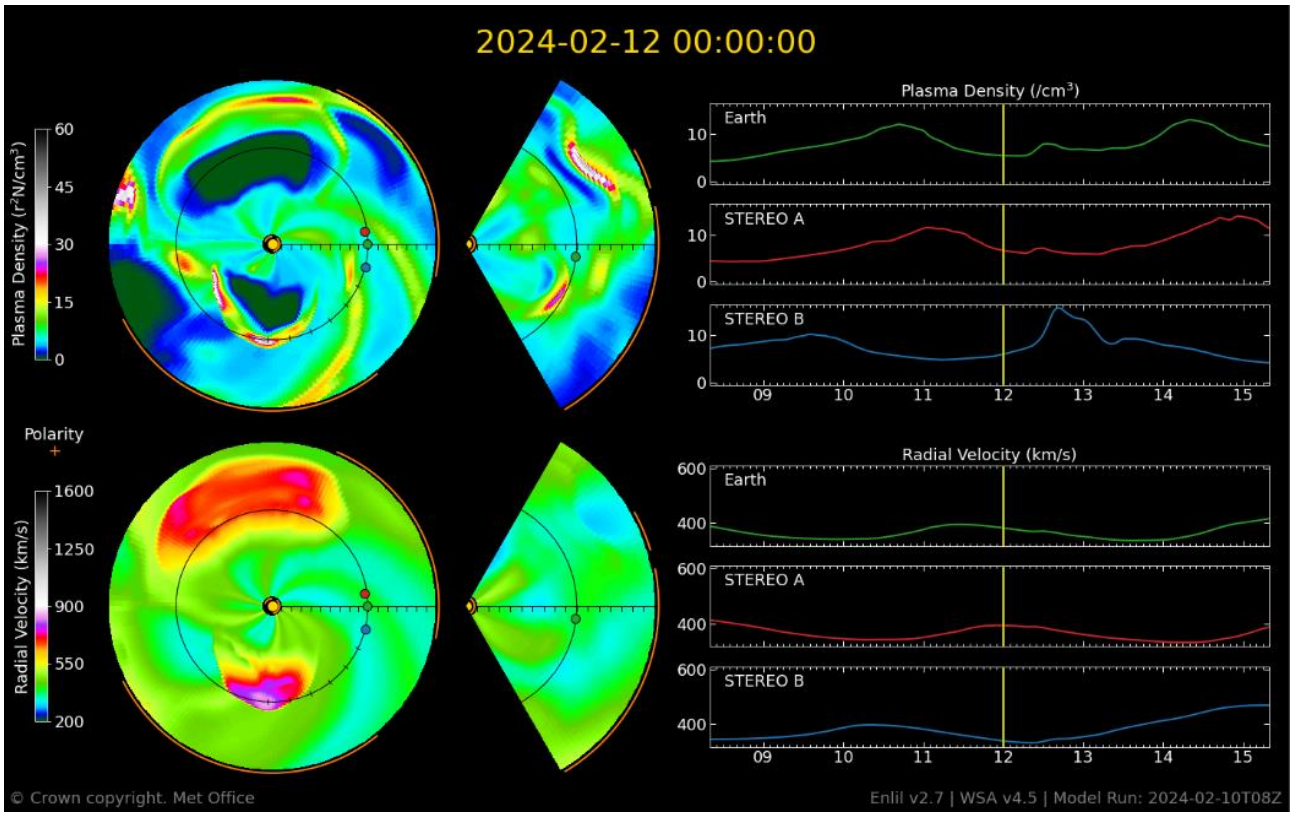

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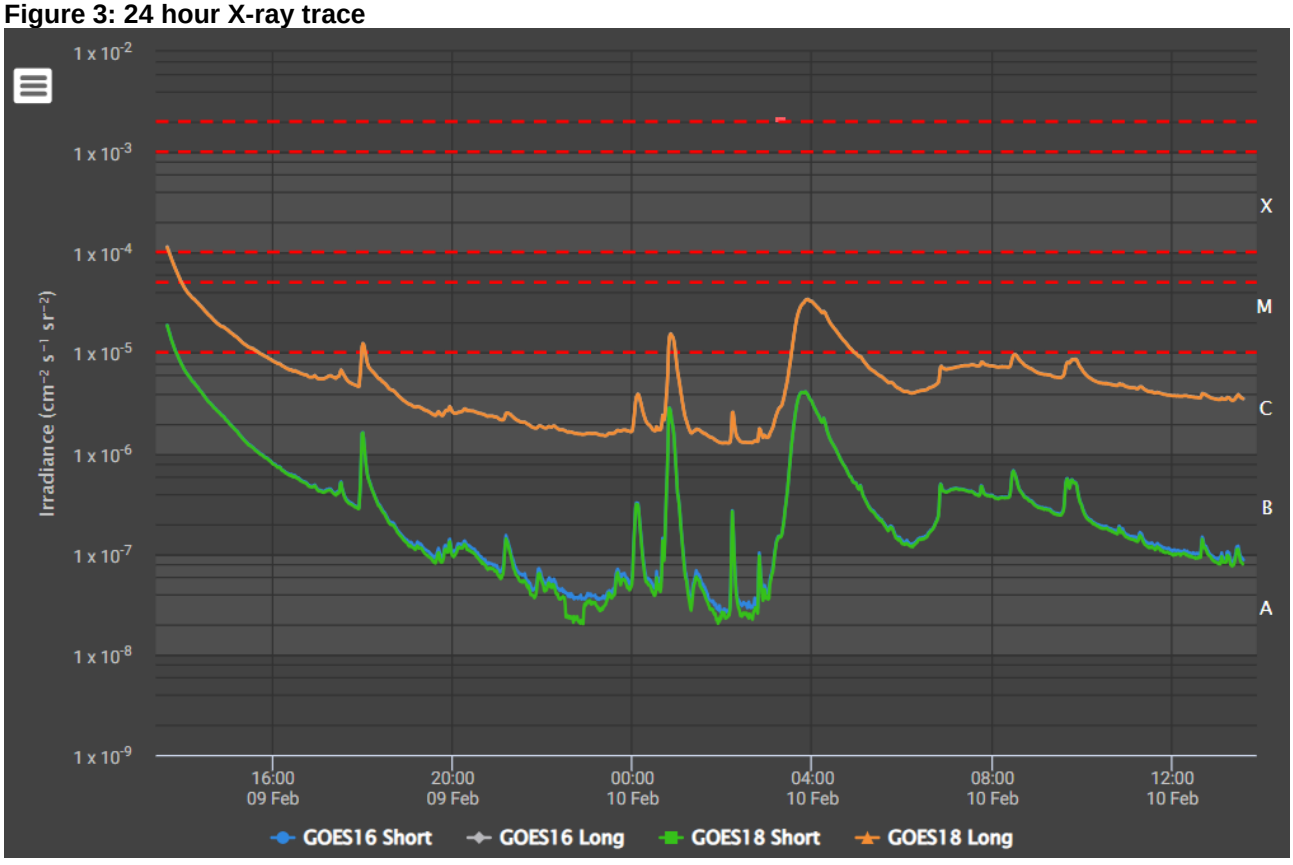
Radio Blackouts - X-Ray Flares:

The risks of flare activity are now dominated by AR3576 near centre-disc with the passing of Ex-AR3575, although the latter does still factor into the probabilities initially due to the possibility it throws emissive ejecta high into the corona, as seen in the past 24 hours.

The daily risk of significant flares is maintained through the period with further M-class flares considered likely from AR3576, with a Slight Chance of X-class. The returning Carrington locations for several past regions are due over the eastern solar horizon in the period - the flux emanating from the first of these is now visible in AIA171 over the southeastern solar horizon, however any contribution from these regions will be assessed as and when they appear over the eastern solar horizon.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	70	70	70	70
Very Active	R3 to R5 X Class	Yes	20	20	20	20

Figure 3: 24 hour X-ray trace



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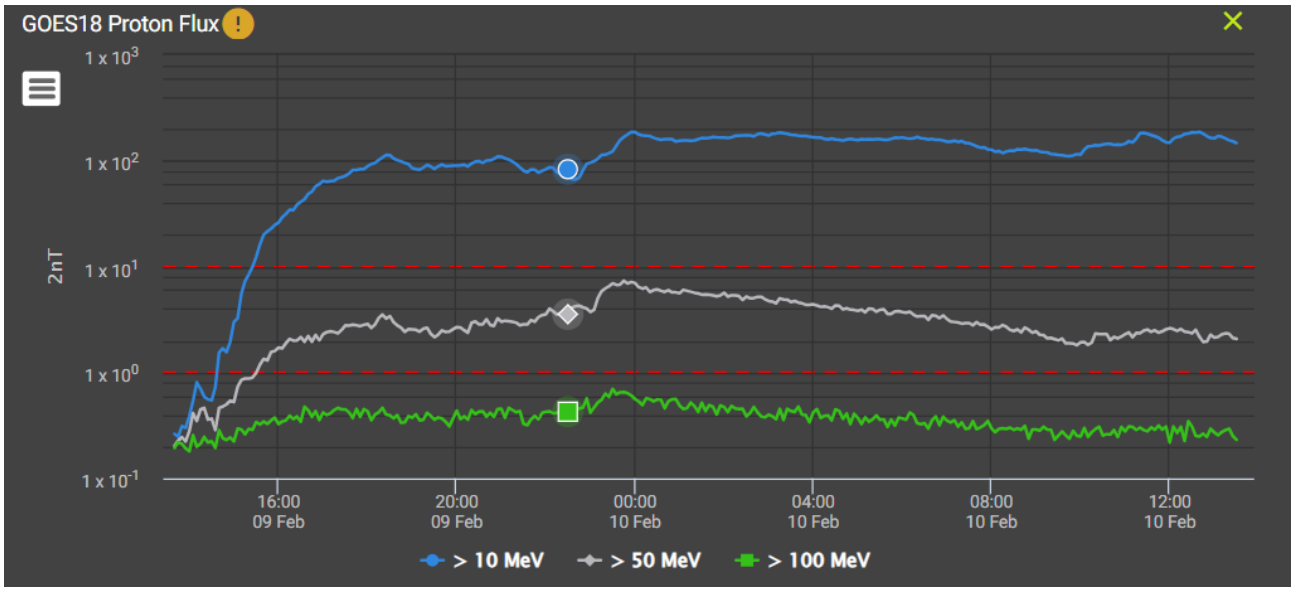
Solar Radiation Storms - (High Energy Protons):

GOES18 high energy (greater than 10MeV) proton flux is currently at S2 levels following the enhancement from the X3.3 flare from 09 Feb, associated with Ex-AR3575. The high energy proton flux should begin to subside through the period, though likley remaining above S1 and perhaps S2 through day 1 (10 Feb), with a gradual fall to below S1 levels possibly by day 3 (12 Feb). There will likely remain an elevated potential to rise above the S1/Minor Radiation Storm level in response to any significant flares into the period, these flares increasingly from AR3576 as it rotates further into the western hemisphere.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	99	80	30	20
Very Active	**≥ S3 ***	No	10	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: 24 hour proton trace



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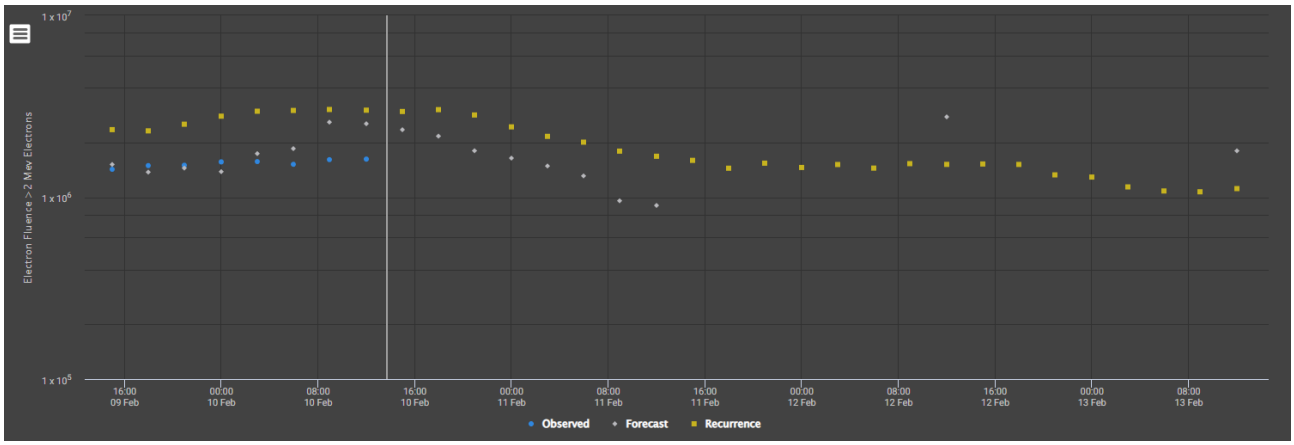
High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) as observed by GOES16 is expected continue at mainly Normal Background levels, given the expected absence of significant fast wind streams and glancing incidence of any CME activity.

The associated 24-hour electron fluence is expected to remain well below the Active (1e8 integrated flux) threshold, as suggested by MOSWOC REFM, although the current forecast period is likely to move away from a predictable coronal hole fast/slow pattern and more towards a threat of CMEs given AR3576's position on the disc, rendering REFM less reliable.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	1	1
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: MOSWOC REFM



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